3(a)	same temperature	**B1**
	no <u>net</u> transfer of thermal energy (between them)	**B1**

3(b)(i)	density	**B1**

3(b)(ii)	*Any two points from:* • large response time / large time to reach equilibrium **or** cannot measure rapidly changing temperatures • reaching equilibrium requires (significant) transfer of energy **or** changes temperature of environment being measured **or** cannot measure temperature of small objects • bulky / difficult to set up **or** difficult to take readings / scale not calibrated to read temperature **or** cannot measure temperature of solid objects	**B2**

3(b)(iii)	substance with large mass **or** temperature that is constant (over time) **or** to calibrate other thermometers (in a laboratory)	**B1**

3(b)(iv)	0 °C = 273 K	**C1**
	T = 273 × (7.83 – 2.31) / (8.69 – 2.31) (= 236 K)	**C1**
	θ = 236 – 273 = – 37 °C	**A1**

Question 3

(a) The meaning of the term thermal equilibrium was generally well understood. It is important for candidates to understand that the temperatures of two objects do not need to be constant for them to be in thermal equilibrium; they simply need to be equal to each other.

(b) (i) Most candidates were able to draw on their knowledge of hydrostatic pressure from AS Level to realise that the quantity needed was the density of the liquid.

(ii) Many candidates did not appreciate the significance of the information in the question, that the system needs to reach equilibrium before the measurement can be made.

(iii) Candidates found this question difficult. This question effectively built on the understanding tested in **(b)(ii)**, with the idea that a constant volume gas thermometer could be used to measure temperatures that are not rapidly changing or temperatures of fluids with large mass (or heat capacity).

(iv) Stronger candidates tended to have little difficulty in establishing the correct answer to this question. Many candidates overlooked the information in the question, that the value of Δh is proportional to the *thermodynamic* temperature of the gas, and attempted to work through the question with the temperature left in °C.

2(a)	work done on / by system	**B1**
	thermal energy supplied to / removed from system	**B1**

2(b)(i)	no thermal energy transferred to / from system (due to lack of time)	**B1**
	work is done on the gas to compress it / to decrease its volume	**B1**
	internal energy increases so temperature increases	**B1**

2(b)(ii)	(during vaporisation) molecular separation increases	**B1**
	(heating causes) potential energy of molecules to increase	**B1**
	kinetic energy of molecules unchanged so temperature unchanged	**B1**

Question 2

(a) Stronger candidates clearly described the context of a system or gas, and were able to identify that work being done or thermal energy being added or removed would change the internal energy of that system. A significant number of candidates mistakenly appeared to believe that changes of work or changes of thermal energy were required to change the internal energy.

(b) (i) Some candidates did not mention a system or gas, making their descriptions inaccurate. Stronger candidates understood that the change was too quick to allow thermal energy to be involved. Weaker answers confused thermal energy with internal energy or temperature.

(ii) Many answers did not refer to molecular energies directly. Descriptions of bonds being broken were common, but stronger candidates explained that both molecular separation and molecular potential energy increased. The link between molecular kinetic energy and temperature was generally well understood.

4(a)(i)	temperature = –273.15 °C	**A1**

4(a)(ii)	temperature = 0 K	**A1**

4(b)(i)	gas is ideal	**B1**

4(b)(ii)	$pV = NkT$	**C1**
	$N = 270 / (8.0 \times 10^{-21})$ $= 3.4 \times 10^{22}$	**A1**

4(b)(iii)	$n = (3.4 \times 10^{22}) / (6.02 \times 10^{23})$ $= 0.056$ mol	**A1**

4(c)	$\frac{1}{2} m\langle c^2 \rangle = (3 / 2) kT$	**C1**
	$\frac{1}{2} \times m \times 1900^2 = 1.5 \times 8.0 \times 10^{-21}$ ($m = 6.65 \times 10^{-27}$ kg)	**C1**
	$m = (6.65 \times 10^{-27}) / (1.66 \times 10^{-27})$	**C1**
	$= 4.0$ u	**A1**

Question 4

(a) Weaker candidates confused the temperature scales in **(i)** and **(ii)**, reversing their answers. Some candidates incorrectly rounded their answer in **(i)** to a whole number.

(b) (i) Candidates were generally able to identify the gas as being an ideal gas. Weaker answers simply gave an expression in symbols without indicating anything about the nature of the gas.

(ii) This question was well answered.

(iii) This question was well answered, with candidates generally using the correct expression, then showing their working in full before expressing their answer to the correct number of significant figures.

(c) Stronger candidates laid out their working clearly, appreciating that an answer in kilograms required conversion to atomic mass units. The final answer was not exactly 4 u, so two significant figures were required. Weaker candidates often did not recognise that an r.m.s. speed was given, which needed to be squared to obtain the mean-square speed. Some candidates were incorrect in the way they expressed the mean-square speed in symbol form, creating an incorrect meaning to their expression.

2(a)	same temperature (as each other)	**B1**
	no net transfer of thermal energy (between them)	**B1**

2(b)(i)	$E_1 = XL$	**B1**

2(b)(ii)	$E_2 = Mc(t - \theta)$	**A1**

2(b)(iii)	$E_3 = Xc\theta$	**B1**

2(c)	$E_2 = E_1 + E_3$	**C1**
	$Mc(t - \theta) = XL + Xc\theta$ **and** completion of algebra to reach $\theta = (Mct - XL) / c(M + X)$	**A1**

Question 2

(a) This question was generally well answered. Where candidates were unable to achieve full credit, it was usually because of an essential missing word in their description, such as ‘net transfer’ or ‘thermal’ (energy).

(b) Most candidates correctly answered all three parts of this question. The most difficult part was **(ii)** because the question asked for the energy *lost* by the water, requiring a positive answer.

(c) This ‘show that’ question required candidates to begin their answer by equating the three energy changes from **(b)**. Stronger candidates did so before rearranging their equation. Attempts to work backwards from the given equation did not meet the requirements of the question.

3(a)	(thermal) energy per unit mass (to cause temperature change)	**B1**
	(thermal) energy per unit change in temperature	**B1**

3(b)(i)	density = mass / volume	**C1**
	mass $= 2.700 \times 10^{3} \times 3.612 \times 10^{-3}$ $= 9.752$ kg	**A1**

3(b)(ii)	volume $= 3.612 \times 10^{-3} \times (2.700 / 2.620) = 3.722 \times 10^{-3}$ m^3 **or** volume $= 9.752 / (2.620 \times 10^{3}) = 3.722 \times 10^{-3}$ m^3	**A1**

3(b)(iii)	$W = p\Delta V$	**C1**
	$= 1.01 \times 10^{5} \times (3.722 - 3.612) \times 10^{-3}$ $= 11.1$ J	**A1**

3(b)(iv)	volume (of block) increases	**B1**
	work is done against the atmosphere so work done (on block) is negative	**B1**

3(b)(v)	thermal energy = $(4.38 \times 10^6) + 11.1$	**B1**
	specific heat capacity = $(4.38 \times 10^6) / (9.75 \times 500)$	**C1**
	$= 898\ \text{J kg}^{-1}\ \text{°C}^{-1}$	**A1**

3(c)	work done is negligible compared with (change in) internal energy so (answer in **(b)(v)** would be) unchanged	**B1**

Question 3

(a) Many candidates defined a quantity that is an energy (often mixing up units with the definition of the quantity), but candidates that gave a dimensionally correct definition of specific heat capacity were usually able to achieve full credit.

(b) (i) This question was generally well answered, though a significant minority of candidates gave an answer to only two significant figures when the data justified four significant figures.

(ii) There were two possible approaches to answering this question, one that used only the primary data in the question, and the other that used the answer in **(b)(i)**. Candidates choosing the latter route needed to appreciate that the volume to be shown was to four significant figures, and that therefore to correctly 'show' this volume, the mass used also had to be given to at least four significant figures.

(iii) This question was generally well answered. Of candidates that knew the correct starting equation, the main reasons for not achieving full credit were either substituting a volume rather than the change in volume, or giving the answer to fewer significant figures than justified by the data in the question.

(iv) Many candidates had the right idea, but there was much confusion between the block, the gas involved (which is the atmosphere), and the 'system' (which is both the block and the atmosphere).

(v) Achieving full credit in this question required evidence of correct application of the first law of thermodynamics, correct substitution of data, an answer calculated to the correct number of significant figures, and an answer given with correct unit. Many candidates achieved full credit, but many others did not meet one or more of these requirements. It is particularly worth noting that some candidates were confused between degrees Celsius and coulombs as the unit of temperature change.

(c) This question discriminated well amongst stronger candidates. Candidates were required to observe that, since the work done (whether doubled or not) is negligible compared with the increase in internal energy, the three significant figure value for specific heat capacity asked for in **(b)(v)** will be unaffected by the pressure change.

3(a)	(thermal) energy per unit mass (to cause state change)	**B1**
	(thermal) energy to change state at constant temperature	**B1**

3(b)	(for vaporisation): involves greater change in volume (of substance) **or** involves greater increase in separation of molecules	**B1**
	more work has to be done by molecules (to separate) **or** greater increase in potential energy of molecules	**M1**
	kinetic energy of molecules unchanged, so more thermal energy needed	**A1**

3(c)	$Q = mc\Delta\theta$ **and** $Q = mL$	**C1**
	$\Delta\theta$ for the water = 26.4 – 10.3	**C1**
	$(37.0 \times L) + (37.0 \times 4.18 \times 10.3) = (208 \times 4.18 \times 16.1)$	**C1**
	$L = 335\ \text{J g}^{-1}$	**A1**

Question 3

(a) The definition of specific latent heat was generally well known, although some candidates did not include the detail that the temperature remains constant to earn full credit.

(b) A comparison of the change in volume or molecular separation and the corresponding change in potential energy of the molecules between vaporisation and fusion was rarely explained well by candidates. Incorrect explanations involving breaking bonds between molecules were common. Very few candidates who had an explanation in terms of volume and potential energy change referred to the kinetic energy of molecules being unchanged.

(c) Most candidates identified the correct equations for heat transfer during temperature change and during state change. However, many candidates did not consider the three processes involved (one state change and two temperature changes). The strongest candidates earned full credit.

3(a)(i)	(P and Q are at the) same temperature	**B1**
	no <u>net</u> transfer of thermal energy (between P and Q)	**B1**

3(a)(ii)	$Q = mc\Delta T$	**C1**
	$24 \times 10^3 = (0.54 \times 390 \times \Delta T) + (0.37 \times 910 \times \Delta T)$	**C1**
	$\Delta T = 44\,\text{K}$	**A1**

3(b)(i)	work done $= p\Delta V$	**C1**
	$= (1.6 \times 10^5) \times (0.18 - 0.32)$	**C1**
	$= -2.2 \times 10^4\,\text{J}$	**A1**

3(b)(ii)	$pV = NkT$	**C1**
	$N = (1.6 \times 10^5 \times 0.18) / (1.38 \times 10^{-23} \times 273)$ $= 7.6 \times 10^{24}$	**A1**

3(b)(iii)	$\frac{1}{2}m\langle c^2\rangle = (3/2)kT$	**C1**
	r.m.s. speed $= \sqrt{[(3 \times 1.38 \times 10^{-23} \times (210 + 273) / (4.7 \times 10^{-26})]}$ $= 650\,\text{ms}^{-1}$	**A1**

Question 3

(a) (i) Generally well answered by the stronger candidates. However, several misconceptions are worth highlighting. Firstly, many candidates appeared to think that ‘constant temperature’ and ‘equal temperatures’ mean the same thing. Secondly, many candidates confused internal energy and thermal energy and gave answers that were contradictory.

(ii) Most candidates knew the general equation for specific heat capacity and were therefore able to achieve the first ‘working’ mark. However, only the strongest candidates correctly analysed the energy transfers involved to arrive at the correct answer.

(b) (i) Many candidates correctly used the equation for work done on a gas when changing volume at constant temperature. However, only the strongest candidates realised that, because the gas is expanding, the work done on the gas must be negative.

(ii) Generally well-answered. However, one misconception that was common in a minority of candidates, warrants mention. Having correctly stated the starting equation $pV = NkT$, some candidates substituted the change in volume from part **(b)(i)** as the value of V.

(iii) Generally well-answered by the stronger candidates. The common confusion among weaker candidates was the difference between r.m.s. speed and mean-square speed. Many candidates stopped at the mean-square speed and gave this as their answer to the r.m.s. speed.

3(a)	(thermal) energy per unit mass (to cause change of state)	**B1**
	(thermal) energy to change state at constant temperature	**B1**

3(b)(i)	$W = p\Delta V$	**C1**
	$= 1.0 \times 10^5 \times 0.017 = 1700$ J $= 1.7$ kJ	**A1**

3(b)(ii)	$\Delta U = Q + W$	**C1**
	$Q = 17.6 + 1.7$ $= 19.3$ kJ	**A1**

3(b)(iii)	mass $= 710 \times 7.2 \times 10^{-5}$ $(= 0.051$ kg)	**C1**
	$L = 19.3 / 0.051$ $= 380$ kJ kg^{-1}	**A1**

3(c)	fusion involves (much) smaller volume change (than vaporisation)	**B1**
	smaller change in intermolecular spacing so smaller change in internal energy	**B1**
	negligible work done (by substance during fusion) so L_F is less (than L_V)	**B1**

Question 3

(a) Full credit for this question was rare, indicating that the definition of specific latent heat is not well known by candidates. Many definitions seen were dimensionally incorrect, defining specific latent heat as an energy rather than as thermal energy per unit mass. The aspect that it is to do with energy needed to change state at constant temperature was more successfully articulated.

(b)(i) This question was generally well answered, with the majority of candidates achieving full credit.

(ii) Most candidates realised the need to apply the first law of thermodynamics, but were then unable to arrive at the correct answer because they did not appreciate that the gas is doing work and so the work done on the gas is negative.

(iii) Full credit by error carried forward from the answer to **(b)(ii)** was common. Weaker candidates found it difficult to work out the mass of the substance, with use of the volume of the gas with the density of the liquid being the common incorrect starting point.

(c) Only the strongest candidates were able to give a response to this question that went beyond IGCSE level physics. These stronger candidates were able to discuss the three terms involved in the first law and how they differ between the processes of fusion and vaporisation.

2(a)	(thermal) energy per unit mass (to change temperature)	**B1**
	(thermal) energy per unit change in temperature	**B1**

2(b)(i)	*Any three bulleted points from:* • the blocks end up in thermal equilibrium • heat capacity of Y is larger than heat capacity of X • no heat loss to the surroundings *Up to 2 points from these six:* • initial temperature of X = 85 °C • initial temperature of Y = 25 °C • the temperature change of X = 45 °C • the temperature change of Y = 15 °C • the temperature change in X is three times that in Y • final temperature of both = 40 °C	**B3**

2(b)(ii)	$\Delta\theta$ = 45 °C for X **and** 15 °C for Y	**C1**
	$mc \times 45 = 1.3 \times m \times 901 \times 15$	**C1**
	c = 390 J kg K^{-1}	**A1**

NOT FOUND:
9702_w24_qp_41 EXAMINER REPORT (Qu 2)

2(a)	(if in thermal contact) no net transfer of (thermal) energy (between them)	**B1**

2(b)(i)	$pV = nRT$	**C1**
	$T = (1.20 \times 10^5 \times 0.0260) / (0.740 \times 8.31)$ $(= 507\ \text{K})$	**M1**
	temperature = 507 – 273 = 234 °C	**A1**

2(b)(ii)	thermal equilibrium so temperatures (of X and Y) are equal	**B1**
	$pV = NkT$	**C1**
	$N = (2.90 \times 10^5 \times 0.0430) / (1.38 \times 10^{-23} \times 507)$ $= 1.78 \times 10^{24}$	**A1**

2(b)(iii)	• (molecular) kinetic energy is proportional to temperature **or** kinetic energy (of molecules) is same in both cylinders • kinetic energy proportional to mass × mean-square speed **or** temperature proportional to mass × mean-square speed **or** r.m.s. speed proportional to √(temperature / mass) • mean-square speed inversely proportional to mass **or** r.m.s. speed inversely proportional to √(mass) *Any two bulleted points, 1 mark each*	**B2**
	r.m.s. speed (of molecules) in X is half r.m.s. speed (of molecules) in Y	**B1**

Question 2

(a) There was a widespread misunderstanding that thermal equilibrium results in no transfer of thermal energy at all between the two objects. Candidates who realised that the rate of transfer of energy between them is constant, and so there is no net transfer between them, were awarded credit.

(b) (i) Very many candidates achieved full credit in this question. As always with a 'show that' question, marks are not awarded for getting to the answer, but for showing the working that leads to the answer. The common reasons for credit not being awarded were not showing the full substitution into $pV = nRT$ or not showing the final subtraction of 273 to convert the temperature from kelvin to degrees Celsius.

(ii) Most candidates were awarded credit for the correct starting equation, but some did not realise that the precision of the data provided in the question demanded a three significant figure answer. Others neglected the 'explain your reasoning' aspect of the question, and did not explain that the temperatures of the two gases are equal as a consequence of their being in thermal equilibrium.

(iii) Many candidates achieved at least partial credit, and many of the strongest candidates were awarded full credit. Among weaker candidates there was considerable confusion between r.m.s. speed and mean-square speed.

2(a)(i)	0 K	**B1**

2(a)(ii)	(measurement) depends on properties of the liquid	**B1**

2(b)(i)	• resistivity varies with temperature • variation with temperature is linear • unique value of resistivity for each (different value of) temperature *Any two points, 1 mark each*	**B2**

2(b)(ii)	thermometer has high heat capacity/specific heat capacity **or** energy transfer needed for thermometer to reach correct temperature **or** thermometer takes time to reach the correct temperature	**B1**

2(b)(iii)	thermocouple	**B1**

2(c)	(variation is) inverse **or** (variation is) non-linear	**B1**

Question 2

(a) (i) There were a number of different misunderstandings shown of absolute zero on the thermodynamic scale. These included values of ± 273 K, temperatures in Celsius and the wrong inclusion of the degree symbol (°K rather than K). This indicates that candidates would benefit from further study of the thermodynamic scale of temperature.

(ii) Stronger candidates appreciated that a temperature measurement using a liquid-in-glass thermometer depends on a physical property of the liquid, whereas the thermodynamic scale is based on the properties of an ideal gas.

(b) (i) Where candidates referred to the quantities of resistivity and temperature in their explanation, they were more likely to be awarded credit. Simply describing the graph as a straight line did not provide an explanation.

(ii) In many cases it was not possible to identify whether a candidate thought there was (wrongly) a delay in the change of the resistance or (correctly) a delay in the thermometer reaching thermal equilibrium with the outside temperature. There were some good answers that referred to the delaying effect of the glass tube and the air inside it on the heat transfer to the platinum. Weaker answers wrongly focused on possible detrimental effects of extreme temperatures rather than rapid changes in temperature.

(iii) The limitations in using a liquid-in-glass thermometer for measuring rapid temperature changes were not understood by many candidates.

(c) Many candidates understood the difference in temperature variation between the two types of thermometers listed in this question.

2(a)	total kinetic energy associated with random motion of molecules	**M1**
	plus total potential energy (of molecules) but potential energy is zero	**A1**

2(b)(i)	$W = p\Delta V$	**C1**
	$= 1.01 \times 10^5 \times 5.20 \times 10^{-5}$ $= (+)5.25$ J	**A1**

2(b)(ii)	$V \propto T$ *or* V / T = constant	**C1**
	$1.24 / (273 + 20) = (1.24 + 0.520) / T$ $T = 416$ K	**A1**

2(b)(iii)	$c = Q / m\Delta T$	**C1**
	$= 960 / (0.016 \times (416 - 293))$ $= 490$ J kg^{-1} K^{-1}	**A1**

2(c)	no change in volume so no work is done (by the gas)	**B1**
	(same temperature change so) same change in internal energy	**B1**
	less thermal energy needs to be supplied so c is less	**B1**

NOT FOUND:
9702_m24_qp_42 EXAMINER REPORT (Qu 2)

2(a)	(thermal) energy per unit mass (to change temperature)	**B1**
	(thermal) energy per unit change in temperature	**B1**

2(b)(i)	work done $= p\Delta V$ $= (2.0 \times 10^5) \times (0.063 - 0.038) = 5000\ \text{J}$	**A1**

2(b)(ii)	gas is expanding (against external pressure)	**B1**
	gas does work / work is done by gas, so (work done on gas is) negative	**B1**

2(b)(iii)	$\Delta U = q + W$	**C1**
	$7600 = q + (-5000)$ $q = 12\,600\ \text{J}$	**A1**

2(b)(iv)	specific heat capacity $= q / m\Delta T$ $= 12600 / (0.35 \times 56)$	**C1**
	$= 640\ \text{J kg}^{-1}\ \text{K}^{-1}$	**A1**

2(c)	same gain in internal energy so same temperature rise	**B1**
	no change in volume so no work done **or** no work done so less thermal energy needed (for same change in internal energy)	**B1**
	less thermal energy needed (for same temperature change) so lower specific heat capacity	**B1**

NOT FOUND:
9702_w23_qp_41 EXAMINER REPORT (Qu 2)

3(a)	no net thermal energy is transferred (between them)	**B1**

3(b)(i)	variation (of density with temperature) is linear **or** each temperature has a unique value of density	**B1**

3(b)(ii)	• variation (of density with temperature) is not linear • region where the density does not vary with temperature • different temperatures have the same density *Any two points, 1 mark each*	**B2**

3(c)(i)	boiling point = 80 °C	**A1**

3(c)(ii)	$Q = Pt$ **and** $t = 21$ s (thermal energy supplied = $810 \times 21 = 17000$ J)	**C1**
	$c = Q / m\Delta\theta$	**C1**
	thermal energy absorbed by beaker = $42 \times 0.84 \times (80 - 25)$ (= 1940 J)	**C1**
	s.h.c. of liquid = $[(810 \times 21) - (42 \times 0.84 \times (80 - 25))] / [120 \times (80 - 25)]$ = 2.3 J g^{-1} K^{-1}	**A1**

3(d)	sketch: straight diagonal line from 25 °C to 100 °C **and** then horizontal at 100 °C	**B1**
	straight diagonal line starting at 25 °C with gradient approximately half that of the original line	**B1**

Question 3

(a) Candidates found it difficult to demonstrate a good understanding of thermal equilibrium. The idea that thermal energy would still transfer between the two objects, but that the resultant or net transfer was zero, was often not known. This was seen through the omission of the word ‘net’. In addition, some candidates did not clarify that the relevant energy was thermal energy.

(b) Candidates needed to refer to the information provided in the graphs. It was common for candidates to refer to the linearity of the relationship, or lack of linearity. Some candidates, however, stated that the relationship between density and temperature for mercury was proportional, which is incorrect. A small number of candidates correctly referred to state changes, but the evaporation of water was not appropriate here.

(c) (i) The majority of candidates correctly stated the boiling temperature of the liquid.

(ii) This calculation proved to be challenging. Many candidates ignored the energy required to raise the temperature of the beaker. A large number of candidates who included the beaker began with the incorrect statement that the energy gained by the beaker was equal to the energy gained by the water. Some candidates calculated the change in temperature correctly as 55 °C but then converted this change into kelvin as if it were a Celsius temperature. This is incorrect physics.

(d) The general shape of the line was correct for most candidates here. Some details were often incorrect, including the approximate gradient of the first part of the line and starting the line from the same temperature.

2(a)	gas for which $pV \propto T$	**M1**
	where T is thermodynamic temperature	**A1**

2(b)(i)	evidence of two temperature conversions between °C and K	**B1**
	two calculations shown, one for each state e.g. $\frac{1.10\times10^{5}\times540\times10^{-6}}{(273+27)} = 0.198$ **and** $\frac{6.70\times10^{6}\times30\times10^{-6}}{(273+742)} = 0.198$	**A1**

2(b)(ii)	work is done on the gas	**M1**
	internal energy increases (so temperature increases)	**A1**

2(b)(iii)	$pV = NkT$ e.g. $N = \frac{1.10\times10^{5}\times540\times10^{-6}}{1.38\times10^{-23}\times300}$ $= 1.435\times10^{22}$ $\Delta E_k = (3/2)\, k\Delta TN$	**C1**
	$= (3/2)\times1.38\times10^{23}\times(742-27)\times\frac{1.10\times10^{5}\times540\times10^{-6}}{1.38\times10^{-23}\times300}$	**C1**
	$= 212\,\text{J}$	**A1**

2(c)	$E = mc\Delta\theta$ **and** $E = mL$	**C1**
	$\Delta\theta$ = (27 + 196) or 223	**C1**
	E = 0.0240 × 1.04 × (27 + 196) + 0.0240 × 199 = 10.3 kJ	**A1**

Question 2

(a) There was much confusion here between the definition of an ideal gas and the assumptions of the kinetic theory. The stronger candidates defined the symbols, including 'thermodynamic temperature' for *T*.

(b) (i) Most candidates were able to use the provided data to show that the helium gas was behaving as an ideal gas. A few candidates omitted the conversion from temperature in degrees Celsius to kelvin.

(ii) Many candidates gave answers that confused internal and thermal energy, and whether the gas is doing work or having work done on it. Many candidates regarded the internal energy and the change in internal energy as the same thing. For example, comments such as 'ΔU increases' were common, where the correct comment would have been either 'U increases' or 'ΔU is positive'.

(iii) Most candidates calculated the change in kinetic energy for a single molecule, rather than the change in the total kinetic energy of the molecules of the gas. A few who completed the correct calculation did not write the final answer to the expected 3 significant figures because the data was given to 3 significant figures. A few candidates incorrectly added 273 to the temperature change.

(c) Most candidates were able to set up this calculation. However, many candidates then made an error with significant figures or subtracting the two energies calculated, rather than adding them. Candidates were confused by the final negative temperature and the removal of thermal energy.

2(a)	(thermal) energy per unit mass (to cause temperature change)	**B1**
	(thermal) energy per unit change in temperature	**B1**

2(b)(i)	work done correct (0)	**B1**
	increase in internal energy correct (+E)	**B1**

2(b)(ii)	work done correct (−W) **and** increase in internal energy same as **(b)(i)**	**B1**
	thermal energy correct so that it adds to work done to give increase in internal energy	**B1**

2(c)	more thermal energy needed so specific heat capacity is greater	**B1**

Question 2

(a) Many candidates found it difficult to give definitions that were dimensionally correct, often giving definitions of a quantity that was an energy rather than an energy per unit mass per unit temperature change. Confusion between quantities and units was another common problem for candidates in answering this question.

(b) Many candidates attempted to give answers that were in terms of different letters from the ones defined in the question. In **(i)**, candidates were expected to realise that the work done is zero when there is no net change in volume, and then to apply the first law correctly. In **(ii)**, they were expected to realise that the work done on the system is negative *W*, and then again to apply the first law correctly to an increase in internal energy that was the same as that in **(i)**.

(c) It was expected that candidates would explain that the second temperature increase required a larger amount of thermal energy to produce the same temperature rise, hence leading to a greater specific heat capacity. There was much confusion between thermal energy and internal energy, and the question was not answered well other than by the strongest candidates.

2(a)	• resistance of a metal • volume of a gas at constant pressure • e.m.f. of a thermocouple *Any two points, 1 mark each*	**B2**

2(b)(i)	$Q = mc\Delta T$	**C1**
	evidence of realisation that Q lost by water = Q gained by mercury	**C1**
	$18.7 \times 4.18 \times (37.4 - T) = 6.94 \times 0.140 \times (T - 23.0)$	**C1**
	$T = 37.2$ °C	**A1**

2(b)(ii)	use a liquid with a lower (specific) heat capacity (than mercury) **or** use a smaller mass of mercury	**B1**

2(c)(i)	depends on properties of a real substance	**B1**
	0 °C is not absolute zero	**B1**

2(c)(ii)	ideal gas	**B1**

Question 2

(a) Many candidates did not understand this question, and gave answers that related to a liquid-in-glass thermometer. Of those who did understand the question, it was common for example to see 'resistance' as an answer without an explanation of what resistance was measured.

(b) (i) This was a complicated calculation, but there were many correct answers. Some candidates were not able to use the data correctly and some used temperatures in place of temperature changes. Some candidates made the calculation more complicated than necessary by converting the temperatures into kelvin.

(ii) The point of this question was that the operation of the thermometer leads to an inaccurate reading for the temperature. Candidates did not seem to realise this and almost all suggested changes to improve the precision of the thermometer rather than its accuracy.

(c) (i) This question proved to be challenging. Many candidates were awarded partial credit for realising that the thermometer measured in °C rather than in K.

(ii) Many candidates answered correctly and realised that the substance is an ideal gas.